# Industrial Quality Control

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## SPECIAL MANAGEMENT ISSUE


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SOCIETY OF QUALITY CONTROL ENGINEERS

IN COOPERATION WITH

THE UNIVERSITY OF BUFFALO

**INDUSTRIAL QUALITY CONTROL**
Editor: Martin A. Brumbaugh,
Crosby Hall, University of Buffalo
Buffalo 14, New York

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# POST-WAR QUALITY CONTROL

George D. Edwards
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During the past few years, the enormous demands for War materials and equipment of all kinds have forced quality control to the fore in unusual degree as a management tool. Both in production and in procurement, the importance of the quality control approach has had increasing recognition not only in this country, but in England, and among manufacturers and purchasers in the other British Commonwealths. Even in Germany, a number of well worked out examples of process quality control have been found.

Prior to this War impetus, it is fair to say that the average management would have been in bankruptcy if it had had no more quantitative information with respect to costs and the other financial factors basically affecting its business than it had with respect to the quality of the materials and equipment which it was purchasing, manufacturing or selling. To be sure, energetic managements knew in general how much scrap material was being produced, and in many cases what proportions of rejects were being experienced. But relatively few manufacturers had any quantitative measure of the quality of the product they were actually delivering to their customers, and relatively few purchasers knew in any quantitative terms what proportions of non-conforming product they were accepting. As a result, not a few manufacturers skated on the thin ice of marginal quality until the ice gave way and they found themselves in the frosty waters of sales resistance.

Almost at the start of War production, the technical military services sensed this situation and began to think to a degree in terms of controlled quality. During the three years following Pearl Harbor, a number of these Services made very considerable progress along these lines. Army Ordnance and Signal Corps actually got fairly comprehensive acceptance quality control procedures into substantially general use. Their inspectors began really to discriminate between satisfactory and unsatisfactory lots of material. If the quality of submitted lots was found not to be controlled at a satisfactory level, their acceptance criteria became more severe. If quality was found consistently better than the acceptable level, their inspection volume was substantially reduced. For the first time, the Services began to have a concept of a quality level which they had a basis for insisting upon, and of the quality of material they were actually accepting.

For the first time also, in many cases, manufacturers were able to get some quantitative idea as to the quality of the material the military were expecting from them. They began to see the advantage of setting themselves up, not just barely to meet this expected level, but to control their quality at a level sufficiently above it to guarantee that acceptance inspection would be on a reduced basis. Under these latter conditions, rejections would be reduced, inventories of completed material would be reduced, less storage space would be required for material awaiting acceptance, acceptance inspection delays would be reduced—the whole gamut of acceptance inspection headaches would respond as to a good dose of aspirin.

But the only way a manufacturer could bring this about was to put adequate process quality control into effect in his plant—to insure that when material reached the acceptance inspection stage, its quality was controlled at a satisfactory level.

So the fact that important military Services had put their acceptance inspection houses in order started a real procession. In plant after plant quantitative discussion of quality levels became a commonplace instead of a curiosity; rational sampling replaced such make-shifts as tray-by-tray inspection; quality control charts began to appear.

Where this system has been in work, savings have been forthcoming from all classes of work, ranging in value from approximately $2.00 to $2,000.00 or more per unit. One recent estimate shows that, without the reduction of the inspection force that will be possible when sampling can be fully resorted to, a saving of 30% in over-all inspection costs can be made. This is also without consideration for saving which Production tells us it is realizing from this mutual teamwork endeavor.

Experience has taught us that this tool should no longer be allowed to collect rust.

This activity created a demand for men who knew something of the background and simpler mechanics of quality control. By conference and training course a number of the military services created nuclei of men in their own organizations who were acquainted with at least the rudiments of the subject. Concurrently the War Production Board established a similar training program for industry people in cooperation with colleges and universities throughout the country. A number of industries undertook similar programs for their own people.

As a result of all of this training work there is now a group of quality control engineers which is numbered in four figures and which is scattered geographically from the Atlantic to the Pacific, and from the Gulf to the Canadian border, as well as in the more important industrial centers of Canada.

Many of these quality control engineers have formed local societies which meet regularly for the discussion and dissemination of information and new developments in connection with the subject. Magazines devoted to it have begun to appear, of which INDUSTRIAL QUALITY CONTROL is perhaps the outstanding example. Substantial progress has been made toward the federation of the local quality control societies into a national organization which should be of increasing value and service to its members.

But the War, which furnished the basic stimulus for all of this, is now over, and the next year or so promises to be an even more crucial period in quality control history. The flush of enthusiasm will fade rapidly unless quality control engineers guide their newborn profession carefully through the troubled waters which are immediately ahead.

Responsibility for such guidance rests particularly upon those quality control engineers who have gained supervisory or management positions. They must use all of their influence to keep their organizations quality minded from the top down.

In the immediate post-War period, competition and the pent-up demand for materials will produce a drive for production and for cutting costs. This drive will be extremely powerful. It must be met with all of the persuasive arguments available as to the advantages of uniform good quality. The high "wantability" of products of uniform good quality, and the overall economy of sound quality control procedures, are of course telling points in such arguments. But the most important point of all is the entire absence of any conflict whatever between sound quality control and attainment of the full objectives of such a drive.

Managements can be convinced of the folly of disbanding effective quality control organizations and procedures, and of the waste which would result from throwing away the valuable knowledge and experience along these lines which control engineers have acquired during War time. To those of us who have seen at first hand the effective results from use of these procedures and the good work of these organizations in War industry, it is almost patent that companies which may attempt to return to guess-work methods of meeting their quality problems will find themselves faced with a kind of competition that they are no longer able to meet successfully.

But responsibility for the future of quality control rests, in an even larger sense, on the shoulders of every individual quality control engineer. It is of course his first duty to know all there is to know about his job. But particularly in the period immediately ahead, he must acquaint himself with, and be on the alert to devise every possible new means of simplifying his procedures. The pretty and statistically perfect solution to a problem will frequently be perhaps 10% or 15% more efficient than a far simpler and more approximate one. But the simpler one will be followed more precisely in operation, and may thus be 10% or 15% more effective than the prettier one. The effect of the simpler and less expensive choice on management's appraisal of the value of quality control will be obvious.

By discussion and dissemination of information as to procedures which have been found simple and inexpensive to operate, and at the same time effective, the local quality control societies can be especially valuable in the immediate post-War years. Amalgamation of these societies into a national organization of the right kind, will enormously enlarge the scope of such dissemination and will contribute correspondingly. Presentation of such information and of new ideas as to methods and procedures, in magazines like INDUSTRIAL QUALITY CONTROL, will be of great value. All of these activities, if carefully aimed in the right direction, can guide quality control through the uncertain period ahead to real service to industry and to the public.

Competition in quality is about to assume a larger place than it has ever had before. Only effective quality control methods can meet simultaneously competition in both quality and cost. Getting such methods into operation is a challenge to every management and to every quality control engineer.

# The U. S. Army Ordnance Department's Use Of Quality Control

H. F. SAFFORD

BRIGADIER GENERAL, U. S. ARMY
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OFFICE, CHIEF OF ORDNANCE

During the past three years the Ordnance Department has been primarily a purchaser rather than a manufacturer. During this time industry delivered materiel to Ordnance at a rate exceeding by many times that which could be produced at our government arsenals. Consequently use of Quality Control methods by the Ordnance Department has been primarily in applications to acceptance inspection of finished items rather than to process control during manufacture.

In the early part of 1942 the Ordnance Department was faced with the problem of a rapidly expanding procurement program and concurrently a greater and greater demand for the release of civilian personnel to meet the draft requirements. Billions of dollars worth of non-industrial materiel was being procured from industry and it was essential that this materiel be safe and effective. Yet every effort had to be made to reduce the manpower assigned to the inspection job. In order to help solve this problem a program was initiated for applying Quality Control methods to Ordnance final acceptance inspection. Perhaps most important among the procedures developed and put into operation under this program were systematic and standardized sampling inspection plans using the now well-known Ordnance Standard Sampling Tables. Definite procedures were provided for the establishment of acceptable quality levels, for periodically summarizing inspection results, and for increasing or decreasing the amount and severity of inspection at each facility, depending upon the quality performance of that facility.

The extent to which this program helped solve the above problem cannot, of course, be measured exactly since other programs and factors had definite bearings on its solution. However, a few statistics will illustrate the magnitude of the accomplishment. Application of Quality Control methods to inspection in Ordnance District Offices was actively started in September, 1942. Beginning that month the number of Ordnance inspectors per million dollars of materiel accepted took a sharp drop from 42 inspectors per million dollars to 12 inspectors per million dollars in April 1943. This remarkable decrease in inspection personnel was the result of an increase in the dollar value of materiel being accepted from five-hundred-million dollars per month to fifteen-hundred-million dollars per month concurrent with an actual decrease in inspection personnel from 20,000 inspectors to 13,000 inspectors. That is, even though the total volume of materiel being accepted was tripled during this period the Ordnance Department was able, through a planned program, to decrease the total number of inspectors by approximately 30%. In numerous instances substantial improvements in quality and reductions in inspection delays were effected concurrently. The Quality Control Program played an important part in permitting the reduction in personnel to be made without any slowdown in production or deterioration in the quality of materiel being accepted.

One of the factors contributing to the success of the Ordnance Acceptance Inspection Program was the use by contractors of Quality Control methods in their process control inspection. An outstanding example of this was in the small arms ammunition industry. To a large degree the success of the Small Arms Ammunition program has turned on the ingenuity of these manufacturers in adapting basic Quality Control principles to fit the peculiar problems encountered in their type of production.

From the above I believe it is obvious that the use of Quality Control methods has resulted in important savings of time, manpower and cost, and has contributed in a substantial way to improving the quality of vital Ordnance materiel.

# INDUSTRY'S USE OF QUALITY CONTROL

ELECTRICAL PRODUCTS

## Quality Control — A Tool of Management

JOSEPH MANUELE

Director of Quality Control
Westinghouse Eleceric Corporation

The last four years have brought out a deluge of literature on quality control — even industrial organizations have published books on the subject, presumably to bring before the public information on how they were using industrial statistical methods for controlling the quality of their products. Four of these booklets have come to the attention of the writer —some with requests that he review them and pass on their merits.

Some of these books have been distributed by companies whose products enjoy a national reputation for quality. Unfortunately the books could not share this reputation. While the method of analysis of data was correct, in some cases the definitions used by the writers and the calculations made were wrong; consequently, the

conclusions arrived at were also wrong. The examples cited in two of the books showed products to be definitely out of control with rejection ratios as high as 65%, and yet the writers, very calmly, made the statement "product out of control—causes unknown." No attempt was made to use the data to improve operating conditions, either through ignorance, indifference or lack of authority.

Publications of this nature do an incalculable harm to the whole science of industrial statistical methods. The fault does not lie with the writers of these works; neither is it the fault of statistics. The real cause is lack of sufficient training in fundamentals. In each case, the writers had been exposed to short courses in the control chart method of controlling quality and then the idea thoroughly inculcated that they were finished statisticians.

The still more unfortunate part of the situation is that some of these literary efforts had been reviewed by instructors and passed upon as finished works in statistical control. The authors were given false encouragement, when a little sincere and honest criticism and sound instruction could have done so much good.

A little reflection will show the danger of such procedure. Certainly, one would not trust the design of the foundation of a skyscraper to a high school freshman, and yet here we are laying the very foundations on which an entire method in industrial quality control is to be built. Either we are indifferent to correction of the lack of sufficient training on the part of enthusiasts or, frankly, we do not know any better.

When properly used, quality control by statistical methods can be an effective tool in the hands of Management. It is certainly an effective aid to engineering judgment. It adds certainty to judgment. This certainty is generally expressed as a per cent and we call it risk; that is, we express an assumption and then say that this assumption is correct "with 95% certainty." All users of sampling tables understand this risk factor.

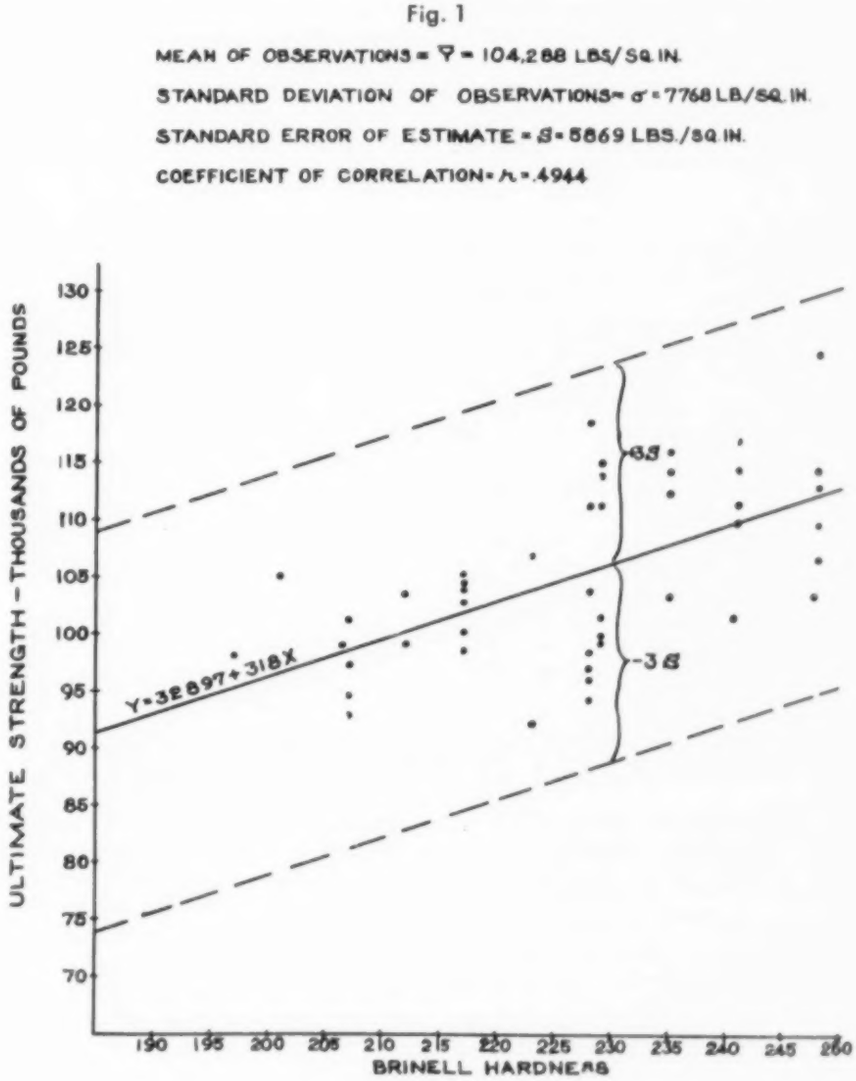
Statistical methods applied to industrial processes will answer such questions as—"Are we doing the best we can?" Within very definite degrees of accuracy such methods will predict the variability of product quality which may be expected from the process during some span of time in the future. It will tell whether the process is poorly adjusted or whether it is unable to produce parts within the prescribed acceptance specification limits. This latter condition we sometimes call "Process out of control," although the process may be in control and rejects still be too high.

However, in order to get such valuable information, the application of industrial statistical methods must be placed in the hands of someone who understands the tool. We certainly would not allow our 6-year-old kindergarten pupil to do his homework on our typewriter. Therefore, why allow a person with the most rudimentary knowledge of statistical methods to work and report results without the benefit of proper guidance.

Industrial statistical methods in the hands of a person who understands what he is doing will reduce costs, increase production, and improve and maintain quality. The person applying the methods need not be a Doctor of Mathematics. It is necessary only that he understand what he is doing. He must be familiar with the statistics which apply to his particular problem, so that he will not draw erroneous conclusions.

To illustrate typical applications of industrial statistical methods, we wish to present three problems taken at random from our files. The first deals with a reduction in cost of heat treated bolts. These bolts were from ¾" to 2" in diameter and varied from 2" to 4" in length. The complaint was that

Fig. 1



"we can buy heat treated bolts cheaper than we can make them." This did not make sense to us, and we asked to be permitted to investigate the problem.

The first thing we did was make a flow-sheet of the process used for producing heat treated bolts. We could see nothing to be disturbed about in the various operations except in the laboratory control setup for determining the quality of bolts.

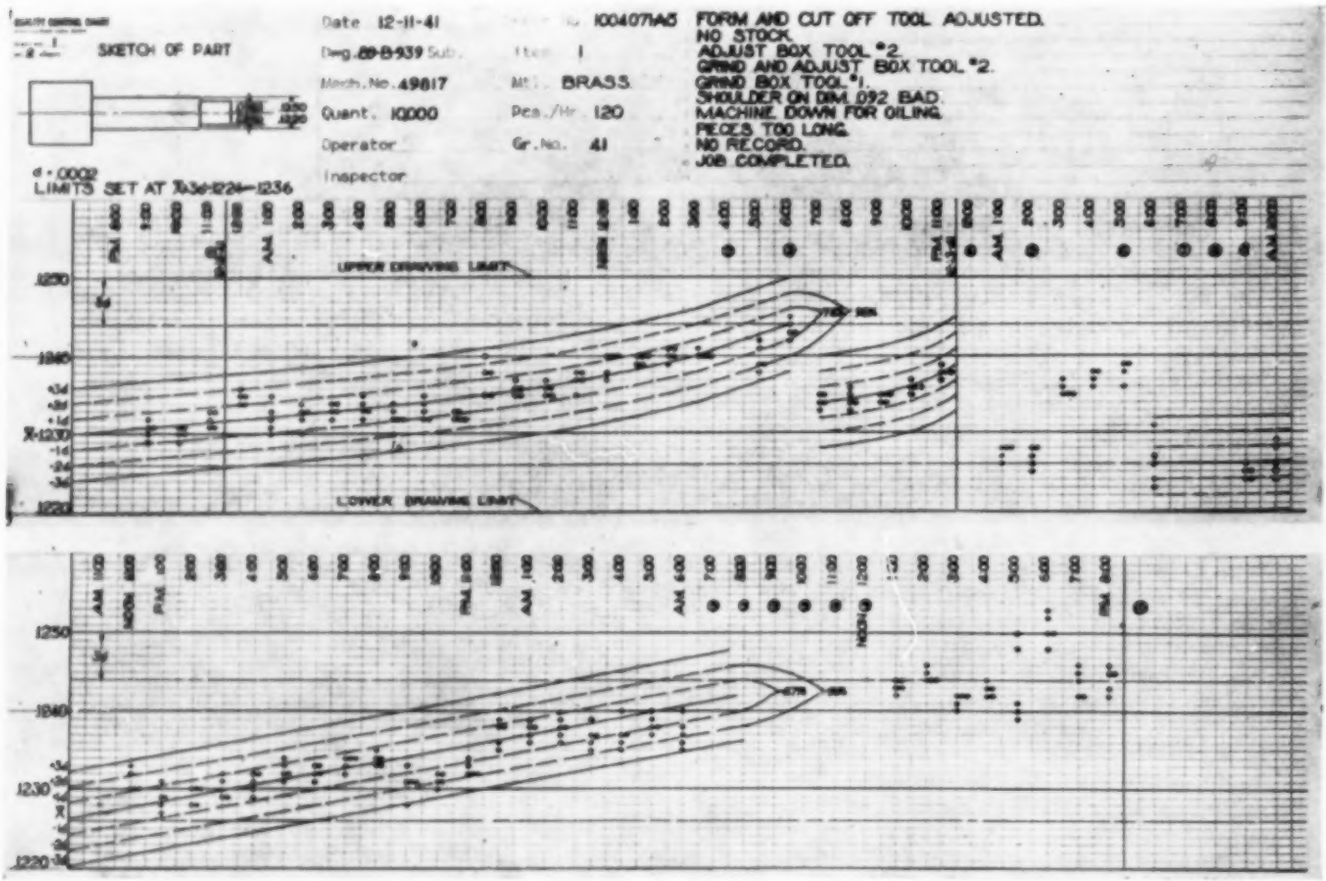
These laboratory tests included a hardness test made in the heat treating department; a standard tensile strength test made in the laboratory and a hardness test also made in the laboratory. We suggested that the hardness test made in the heat treating department be used as a measure of the tensile strength of the bolts. We were told that these bolts were "made of a special alloy steel" and no information was available on the relation between hardness and tensile strength.

We could see in this problem a simple application of the principles of linear correlation. Therefore, we determined the relationship between the hardness as determined in the heat treating room and the tensile strength of the bolts. For this determination, we used the laboratory records of tests made during the previous six months. Our results were presented in the form of a chart with 3σ-limits (See Fig. 1). The result was the elimination of the tensile strength test with a resultant savings of 10c per bolt, which enabled the Shop to meet outside competition very effectively.

The second problem we should like to discuss is one involving increased production. To make the presentation simple, we have chosen to take production on Brown & Sharpe 00 Automatic Screw Machines. Generally these machines are rated to produce so many pieces per hour; therefore, the rate of production times the number of hours of operation should tell us how many pieces to expect per day. Actual production is from 40% to 60% of this theoretical amount. The reason for this loss in production is that the operator is constantly "hunting" a setup which will give him the quality of product which is required. The usual method is for the operator to take a part and measure it. If the particular part happens to be toward the low limit, he will stop the machine and set it up higher. Conversely, if the part happens to measure toward the high limit, again he will stop his machine and set it down toward the low limit. This constant "hunting" results in loss of production and defective parts.

Familiarity with the frequency distribution curve would tell the operator that he must expect parts toward the lower side and upper side of the specification limit — parts will be produced which naturally fall under the tails of the frequency distribution curve with a grouping or concentration near the middle of these two points. Failure to distinguish between the quality of individual parts, as distinguished from the average of several parts, leads to considerable hunting in setup on the part of the operator. This hunting may, and

Fig. 2



often does, result in spoiling a perfectly good setup.

The answer to this situation is to make a simple distribution of a small sample of parts — say 25 to 50. If the distribution is satisfactory and falls entirely within the specification limits, the operator should allow the machine to run without making any changes. Subsequently, if he will take only four or five pieces every hour or so and note their size or quality, it will give him all of the information he needs for controlling the quality of the parts. It is necessary that these four or five pieces taken hourly should fall within the pattern of the frequency distribution curve obtained when the original analysis was made.

By such methods production on Brown & Sharpe 00 has been increased by as much as 50% (See Table I). Runs of as much as 20 hours to 25 hours have been obtained. During these runs production averaged as much as 95% of the theoretical quantity (See Fig. 2).

Statistical methods may be used to analyze a problem to determine whether the part can be made within the prescribed specification limits. The problem generally arises as the result of a discussion between the manufacturing department and the engineering department. Generally, the manufacturing department insists that the engineering specifications "are too tight and the part cannot be made." The pressure is on the design engineer to widen the specification limits. Necessity then arises

**TABLE 1**

| Item | Jan. 8 Cont. | Jan. 9 No Control | Jan. 10 Control | Jan. 11 No Control | Jan. 12 Control | Jan. 13 No Control | Jan. 14 Control | Average No Control | Average Control | % Incr. with Control |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 930 | 830 | 803 | 940 | 980 | 970 | 985 | 913 | 925 | 1.1 |
| 2 | 593 | 330 | 637 | 460 | 830 | 672 | 997 | 487 | 764 | 56.9 |
| 3 | 904 | 824 | 746 | 530 | ..... | ..... | ..... | 677 | 825 | 21.9 |
| 4 | ..... | 3,700 | 4,980 | 5,100 | 4,500 | 4,800 | 4,400 | 4,533 | 4,627 | 2.1 |
| 5 | 3,094 | 3,190 | 3,230 | 3,150 | ..... | ..... | ..... | 3,170 | 3,212 | 1.3 |
| 6 | ..... | 1,980 | 2,251 | 2,535 | 2,508 | 2,350 | ..... | 2,288 | 2,375 | 3.9 |
| 7 | ..... | ..... | 626 | 700 | 644 | 270 | 620 | 485 | 630 | 29.9 |

**TABLE 2**

| Mold # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $\bar{X}$ | .2471 | .2535 | .2578 | .2573 |
| $\sigma$ | .000918 | .000918 | .001025 | .000589 |
| $3\sigma$ | .002754 | .002943 | .003075 | .001767 |
| Mold | 5 | 6 | 7 | 8 |
| $\bar{X}$ | .2559 | .2599 | .2576 | .2542 |
| $\sigma$ | .000840 | .000701 | .000507 | .000604 |
| $3\sigma$ | .002520 | .002100 | .001521 | .001813 |
| Mold | 9 | 10 | 11 | 12 |
| $\bar{X}$ | PIN | .2513 | .2589 | .2510 |
| $\sigma$ | BROKEN | .000493 | .000961 | .000522 |
| $3\sigma$ | | .001389 | .002883 | .001566 |
| Mold | 13 | 14 | 15 | 16 |
| $\bar{X}$ | .2572 | .2532 | .2558 | .2571 |
| $\sigma$ | .000708 | .000660 | .000750 | .000660 |
| $3\sigma$ | .002124 | .001980 | .002250 | .001980 |

**TABLE 3**

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $\bar{X}$ | .2444 | .2446 | .2442 | .2460 |
| $\sigma$ | .0006 | .0005 | .0009 | .0012 |
| $3\sigma$ | .0018 | .0015 | .0027 | .0036 |
| | 5 | 6 | 7 | 8 |
| $\bar{X}$ | .2454 | .2461 | .2446 | .2442 |
| $\sigma$ | .0008 | .0008 | .0009 | .0007 |
| $3\sigma$ | .0024 | .0024 | .0027 | .0021 |
| | 9 | 10 | 11 | 12 |
| $\bar{X}$ | .2444 | .2432 | .2436 | .2458 |
| $\sigma$ | .0009 | .0006 | .0008 | .0006 |
| $3\sigma$ | .0027 | .0018 | .0024 | .0018 |
| | 13 | 14 | 15 | 16 |
| $\bar{X}$ | .2441 | .2445 | .2453 | .2450 |
| $\sigma$ | .0007 | .0007 | .0007 | .0006 |
| $3\sigma$ | .0021 | .0021 | .0021 | .0018 |

for some unbiased study to be made to determine whether or not specifications are really too tight or whether the Shop has failed to use production methods to the fullest extent in order to produce the parts within acceptable limits.

The analysis consists of determining the true average quality and the true variability of the quality of the parts **as currently produced**. Having this information, true average and true range of quality, a decision can be reached as to whether the pressure should be applied on the shop organization to improve their methods, or whether the engineering design shall be changed.

This problem is illustrated by a moulded pulley (See Fig. 3), which

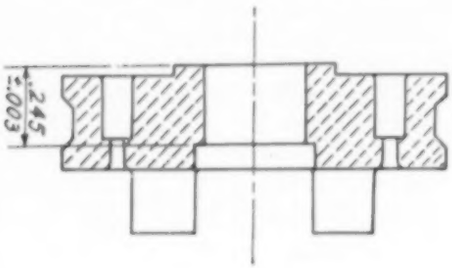



Fig. 3

was required to be made with a tolerance of ± .003". The Customer Department was reporting 78% of parts coming outside specification limits. The manufacturing department insisted that these parts could not be made within a tolerance of closer than + .003" and −.006".

A number of these parts were measured and it was found that the average was considerably above the nominal dimension required by the engineering design. However, the variability, or range, was about .0019", whereas the design specifications allowed .003". This indicated clearly that the process would produce parts within the required tolerance (See Table 2), but the control was at the wrong point, $\overline{X}$ was too high.

Consequently, adjustments were made to the moulds and subsequent inspection of 15,000 parts revealed only six parts as being outside the specification limits, and these were only within one or two ten-thousandths of an inch from the specification limits (See Table 3).

This improvement in quality resulted in the elimination of three inspectors and a finishing operation as well as substantially increasing production.

Industrial statistical methods applied to the control of quality are recognized as definitely established tools of management. The day has passed when it was necessary to "sell statistical methods to Management." Quality control no longer needs Management. However, Management will do well to adopt the methods of industrial statistics to reduce costs to meet competition, increase production to satisfy growing markets, and to improve quality to meet the tastes of a discriminating public.

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RADIO INDUSTRY

## "Peacetime Responsibilities and Opportunities in Quality Control"

ANDREW I. PETERSON

Manager Quality Control Department, Radio Corporation of America

Successful competition demands better quality control in manufacturing—and the men to do it. With mechanization, specialization, and complexity of operations, and progressively disciplined observance of quality standards, the profit margins are critically dependent upon controlled continuity and performance.

In essence scrap, rework, and trouble-shooting arise from excess variations and instabilities in products and processes. These propagate from variable elements and factors underlying each stage of processing. It is directly and indirectly prohibitive to screen-inspect all parts and materials at all stages of processing. But experience with statistical quality control has proven that proper sample checks and techniques applied to product and process factors can provide stability and large savings. Formerly, with apparently unassailable complexity of variables and the usual reliance upon the intuition of the craftsman, we were content to rationalize the past and to make standard-cost allowances for "normal" scrap, make-up, and insidiously hidden costs derived from insufficient control. One brief study of differentiated manufacturers indicated avoidable costs of from 15% to 25% of manufacturing costs. What would your department or plant manager do for a part of this, if you **and** he knew where and how to get it?

A common complaint is that management cannot be sold. True, we are in a stage of development where managements need enlightenment too. They should have at least the degree of faith shown when gambling on a new product line. It takes time to change years of ostrich-like habit. But management cannot hand out blank checks. Therefore, direct approach is through the pocketbook. If we are good production and quality control men, we prepare work sheets of where and how much the costs are from scrap, rework, and trouble-shooting. Failing this, show how good you can be at your own job.

The **How** depends upon you. We have had a spate of purely statistical technique in quality control—by men who have not been in industry. Necessary as it is, it is far from sufficient in the technical production of today. The specialist must have full command of technology, management, and statistics in the same person. The newest of these is statistics, providing a better understanding of how and what variations accumulate in a process.

It is a general and humble belief that we have barely scratched the surface of industrial quality control, and that one way of rounding out our progress is through developing broad competence in technical and statistical control. The support of quality control societies for the exchange of experience is one of the best ways of growing up with the profession. But the aspirant to managerial or professional success must look beyond the erudite side-show barker. We hold the future of a real and indispensable profession. However, there must be basic training in statistics for the many whose jobs support the administration of quality. Cooperative understanding by inspectors, foremen, and operators, who really make the wheels go around, is necessary for successful development. The largest problem in plant control is people.

## QUALITY CONTROL IN THE RADIO INDUSTRY

J. CLARK RYAN,
Works Manager,
Colonial Radio Corporation

The practice of using statistical techniques which has come to the fore during the war years to aid in the control of quality of repetitive processes can result in a reduction of overall manufacturing costs. Whether or not this reduction takes place depends upon the skill of applying these techniques to the individual case. The establishment of any new department or an expansion of an existing one must justify itself by a reduction of total costs.

Quality control in the sense that the term is used today was introduced to this plant in November, 1943. Results cannot be estimated too precisely but it is safe to say that the quality of product has been materially improved, and that notable savings have been accomplished through adjustments of operating and inspection procedures. Perhaps the greatest gain for the future lies in the establishment of an objective basis of understanding between suppliers and plant engineering, manufacturing, inspection, and management.

With this end in mind all incoming inspection, manufacturing, assembly, testing, and final inspection operations are under scrutiny. Where other techniques offer advantages, they will be used. Where the scales are in favor of the statistical techniques, maximum use will be made of them. Indications are that a great deal is to be gained through their employment.

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## STEEL PRODUCTS

## "Quality Control at Work"

P. C. CLARKE
Asst. General Manager,
Hunter Pressed Steel Company

Quality control techniques based on the statistical method have been in use for a number of years in the various departments of this company. The experience gained with this modern inspection method has given us the opportunity to evaluate accurately the reduction in manufacturing costs and improvement in quality which have resulted from its application.

Industrial plant managers who still hesitate to adopt this modern method in their own organizations apparently do so because the word "Statistics" seems to suggest that, as a minimum requirement, key inspection personnel would have to be some sort of junior statisticians. Perhaps a short description of our own experience will serve to show that such a concept is wholly mistaken.

Our inspection personnel, with only a minimum amount of training in the technique, have readily absorbed and applied these newer concepts of quality control without the slightest bit of trouble. No changes in personnel have been found necessary. All control charts, frequency distributions and correlation charts are handled by female personnel having average intelligence. This particular group of girls does all of the measuring and testing of samples, performs all of the necessary calculations, prepares its own control charts and records all inspection results thereon. Lead inspectors are, therefore, free from all of this type of detail work and can devote all of their activities toward interpreting the control charts and taking action when necessary.

Inspectors are no longer the boys whose chief function it was to rule O.K. or N.G., scrap, rework or pass and then sit back and let the factory do all the worrying. Instead we find that today the closest possible cooperation and harmony exists between inspection and manufacturing personnel. Solutions to difficult problems are obtained with minimum loss of time and friction.

The factory personnel, due to their closer association with the quality function, are able to obtain readily the results of changes in the manufacturing process, so that intelligent decisions can be made regarding the degree of improvement in quality which any particular change has produced. The net result of all of this has been to reduce production costs through increasing machine speeds, decreasing machine time, reduction in the amount of 100% inspection, higher yields through reduction in scrap and elimination of unnecessary operations. Indeed, the results have been so satisfactory to this company that plans have been made to increase further the inspection personnel, since it is now evident that any reasonable increase in inspection cost will be more than offset by the reduction in manufacturing costs which will obtain.

To be specific we might mention that on two particularly difficult fuse components the estimated reduction in cost directly assignable to the application of these quality control techniques was sufficient to defray the entire cost of the inspection department for a period of almost one year. While these were outstanding examples, proportional savings are constantly being made on many other jobs. These results are not extraordinary with our company but have been duplicated in hundreds of other plants wherever use has been made of this modern inspection tool.

Plant managers who have not yet adopted this valuable method can scarcely afford to continue to overlook the proven advantages in cost and quality which the method offers.

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## "The Economics of Quality Control at the English Needle & Fishing Tackle Co., Studley, Warwickshire, England"

WILLIAM A. BENNETT
Works Manager,
Engineering Division

The savings effected by the introduction of Quality Control through statistical methods at the English Needle & Fishing Tackle Company are rather intangible, since the value of its achievements cannot be expressed specifically in monetary terms. That savings have been effected is beyond dispute, but these are essentially of a short-term nature, brought about by the fact that Quality Control is the medium for portraying certain industrial inefficiencies arising from assumptions based upon arbitrary judgment.

The acceptance of quality principles by the manufacturing organization has been brought about mainly through achievements in the effective coordination of the various functions of the manufacturing

unit. These achievements can be expressed as follows:

1. Integration of the inspection function into the process of manufacture by providing, (a) the means of carrying out a more positive operation (b) the partial elimination of the end product inspector who, through the negative function, becomes destructive and often fails to achieve the hundred percent quality desired.

2. Provision of factual knowledge, regarding process capabilities, leading to (a) a better appreciation of machine and human limitations, (b) the elimination of injustices, either imaginary or real, which are brought about by ill-considered opinions, (c) more careful consideration given by originators of specifications, and designers who often introduce limits and tolerances on an arbitrary basis, sometimes with complete disregard to their consequences and effects on economic manufacture, (d) the determining of economic levels of quality which in turn can be used by a purchasing agent in the selection of suppliers of purchased material and part fabricated products.

3. Economic distribution of machines and operatives by their classification through the medium of quality control technique into grades of ability to meet process limits which are not subject to personal opinion or bias.

4. Reestablishment of pride of workmanship, which was inherent in the craftsman but which has been partially lost by the introduction of more individualistic repetition production.

### EDITOR'S NOTE

Messrs. Maurice Milbourn and William A. Bennett from Birmingham, England, are now visiting our manufacturing centers to observe Statistical Quality Control. It is notable that their trip is financed by prizes given by Birmingham manufacturers for the best two contest papers on the subject. The attached table from Mr. Bennett's paper has a tabulation of general applications of information provided by statistical quality control, which will be of great interest to the many in collateral functions of manufacturing rather than in direct specialization for process quality control.

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Application of Information Made Available by Statistical Quality Control to the Process of Manufacture
Statistical Quality Control Bureau as means of arriving at Data

**Process Planning Department**

(1) Aids to Estimating
- (a) Reliable information regarding Scrap Allowances
- (b) Selection of machines on basis of existing data
- (c) Set levels of Quality
- (d) Ability to meet specification

(2) Aids to Production Control
- (a) Production Control aided by S. Q. C. Adaptation of Shop Charts giving breakdown of causes for Machine Stoppages
- (b) Immediate notification of Excess Scrap
- (c) Payment by Results from Sampling Technique
- (d) Elimination of uneconomic and waseful operations

**Technical Functions**

(1) Aids to the Planning of Tool Layouts
- (a) Suitability of Tool Set up
- (b) Determination of Economic Drawing Tolance
- (c) Comparison between Mechanical and Hand Controlled operations
- (d) Effect of Auto Cycle Time on Quality

(2) Information regarding limitations of Machines
- (a) Limits of Concentricity
- (b) Variations in parallelism
- (c) Limits on Ovality
- (d) Limits on lengths to be expected with different types of stops

(3) Preliminary Tryouts
- (a) Numerical Proof of Experimental or preliminary runs before handing over to production
- (b) Ability to meet Specification with estimated requirements

(4) Aids to Control over Existing Processes
- (a) Analysis of Tool Wear
- (b) Periodic review of accuracy of jigs and fixtures from S. Q. C. Charts
- (c) Machine Maintenance
- (d) Effects of Subsequent operations on previously controlled dimensions

**Production Control**

(1) Supervision
- (a) Control of Setters and Operators by review of dispersion of Means
- (b) Machine Control by review of Daily Mean Range Values
- (c) Indication of Maintenance requirements
- (d) Control of process operational scrap by Fraction Defective and Dimensional Charts
- (e) Effects of Incentive Bonus on Quality
- (f) Numerical Proof of ability to meet specification requirements from results of trial run
- (g) Diagrammatic Relationship of Process to Engineering Limits
- (h) Reliable Proof of quality

**Inspection**

(a) Levels of Quality within fixed Limits
(b) Comparison between Shop and Final Inspection Standards

## FOUNDRY

### "Statistical Quality Control in the Foundry"

R. W. S. FREEMAN
Ontario Research Foundation

When mechanization is introduced into a foundry it is a step towards the establishment of controlled foundry conditions, and in effect, it is an attempt to control one or all of the fundamental divisions of the foundry. The divisions of a foundry may be itemized as follows:

1. Sand conditioning, from the shakeout through the cycle and back to the moulding station.
2. Moulding, i. e. the production of moulds and their conditioning previous to pouring.
3. The composition, treatment and properties of the metal both in the molten and solidified state.
4. The quality of the cast product, and this includes a consideration of the time and labor expended on such operations as chipping and repairing.

Recently it has been shown by practical applications that statistical quality control methods are well suited to assist in establishing, and maintaining, control over all of the above-mentioned process and product variables.

Whether the sand is conditioned in batches, as in a muller, or continuously as in a pug-mill, quality control charts are a handy and positive way of studying the efficiency of both operators and machines. Sand samples are drawn on a time basis and tested in the usual manner for compressive strength, permeability, and moisture content. In addition to these, hot and dry strength tests can be made along with the very important expansion and contraction tests. These data in the form of a control chart show when action is necessary, not so much to remedy out of control conditions, but rather to counteract serious trend conditions which are so often present in sand. The average foundry man will say that control charts on sand properties tell him nothing, because he can tell more by its feel. That may be so, but the fact remains that by posting quality control charts for sand properties and taking action when necessary, a better control over the sand is quickly obtained.

One of the principal properties of the mould when ready for pouring is the mould hardness. Again individual spot tests do not show the overall conditions; it is the control chart which shows whether or not the variations are due to chance or to assignable causes.

A large number of foundries do not have a chemical testing laboratory and it is impossible for such organizations to weigh properly any variations in the chemical analysis of the metal. However, for those organizations which can check chemical compositions there are many ways of improving the process. Control over the analysis is essential, of course, but it is more important that the alloying materials be present in percentages no greater than physical performances require. Such a determination can not be made by a few individual studies of chemical analysis and physical property relationships but should be studied by means of correlation or contingency tests.

The final product quality is so closely related to the chemistry and moulding floor practice, that it seems difficult if not impossible to decide what conditions resulted in accepted or rejected castings. However this problem also is solved by statistical methods. The quality of the casting, based on hardness, size, clean-up time or machinability can be readily established by physical tests, and it is a simple matter to study statistically this measure as it is related to the different process variables. This study can either be by correlation or contingency tests.

In this short statement no attempt has been made to give details of the application of quality control in a foundry, but rather specific statements have been made to indicate that it does function to the advantage of all persons concerned with the quality of the castings. For those who are interested in an actual application the following article is available in reprint form:

"Statistical Control of the Manufacture of Manganese Steel Track Shoes," by A. E. R. Westman and R. W. S. Freeman of the Ontario Research Foundation, Queen's Park, Toronto, Ontario.

For those who are interested in the application of statistical methods to the production of die casts, the writer would refer them to,

Production and Engineering Bulletin, Ministry of Supply, London, England Volume 4, Number 28, April 1945, "Quality Control in Die Casting."

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## TRACTORS

### "Quality Control"

FREDERICK J. HALTON
Assistant to the President,
Deere and Company

Statistical Control Technique was introduced initially at the John Deere Tractor Works. The results were so convincing that an immediate decision was made to bring the system to our other plants. In doing this we set up a one-day meeting at the head office which was attended by the plant managers of all operating divisions and the policy making executives of the head office. The principles of Quality Control were explained and results already obtained were presented. The services of quality statisticians were offered to the plant managers, but they were encouraged to select quality engineers within their own organizations. It should be noted that no compulsion was employed at any stage. The reaction of the plant managers was in general favorable, but not unnaturally they preferred to move slowly, particularly since we insisted that the quality control department should occupy a position on the plant's organization chart parallel with Production, Inspection, and Engineering. However, is is a pleasure to report that within two months all plants had some quality control work in progress and most of them had well established departments.

In more detail the steps employed in introducing a quality control program in a plant may be listed as follows:

Use in-plant training programs to train top-executives on what Quality Control is and the results that can be accomplished.

Make a survey for initial application.

Make an initial installation and submit the results back to top management.

Use the in-plant training program to train employees to **design** and **operate** the program.

Use the in-plant training program for production supervision, foremen, sub-foremen, etc.

Launch the program under the guidance of a qualified Quality Control Engineer.

We have reaped definite evaluated savings from our Quality Control program thus far, but we know that the big gains lie ahead. Some improvements are a matter of record. On one grinding operation a 35 per cent rejection rate was eliminated and 100 per cent screening inspection was replaced by a sampling inspection plan with corresponding reduction in inspection personnel. The rejection rate on brass bar machining was reduced from 14 per cent to one per cent. Statistical analysis provided the only factual basis for a $90,000 saving on one high speed machine. Vendor relations were improved after purchase specifications and receiving inspection were placed on a factual statistical basis.

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## GAGE MANUFACTURE

## "Quality Control —Management's Guardian"

CLINTON V. JOHNSON
Chief Engineer
Johnson Gage Company

Editor's Note: This article is written in the style of a letter.

In all fairness, however, we should admit the probability of a prejudiced point of view in favor of Quality Control—for we have been directly connected with the design, manufacture, and the sales and application of "measuring and gaging devices" for approximately twenty-five years. We insist, however, that we have faithfully applied in our own plant our advice to others.

Our approach to the problem of interchangeable manufacture, as a review of our teachings will confirm, always emphasized "prevention of error" and "controlled production." We stressed the economic significance and advantages of proper inspection at the right place; that effective inspection could well mean LESS inspection—with INCREASED quality control and production as a direct consequence.

While it is not compatible with the spirit of our organization to feel satisfied, we firmly believe that we are correct and justified in stating that our recognized achievement for quality and production during the period of national peril was directly due to a practical application of the principles of quality control consistent with the setup of our organization and the product manufactured.

Quality and production were the obvious results of following simple horse sense "quality control" policy: through proper engineering, particularly as regards tolerance specifications; suitable machine equipment (and working conditions); properly guided and supervised operators; effective process inspection methods and available equipment; immediate (manufacturing department) analysis of error (or trend toward error); immediate and authoritative elimination of "cause of error"; operator responsibility and accountability; and recognition of operator proficiency by management.

With pardonable pride we state that the overall score during these years of unprecedented problems was a customer rejection (for cause) of an insignificant part of one percent—our "in process" scrap-box was correspondingly small.

The domestic (and probably international) competitive intensity which the gage industry is confronted with causes Johnson Gage Company to regard an effective "Quality Control" program in its plant as indispensable to survival, and vital to its success. Further, from the lessons already learned (and from continuing reports on foreign accomplishments) we regard it a patriotic duty, particularly in our role as gage manufacturers, to demand of our organization maximum manufacturing effectiveness from both economic and technical standpoints.

Quality control has very aptly been referred to as "Management's Newest Tool." We suggest the following variation: "An effective Quality Control system is Management's Guardian—an effective Inspection Department is the Customer's Representative."

## "Quality Control a Bargain"

C. W. KENNEDY
Manager Quality Control
Federal Products Corporation

Getting something for nothing appears to be a constant human goal. The bargain counter complex is not confined necessarily to the female of the species. And one of the deeper pleasures in life is derived from that occasion when a true bargain is discovered.

The application of Quality Control and its simple, mathematic-statistical approach in manufacturing proves to be one of those unusual bargains. With its use, certainly more is obtained for less.

In our own plant, as a specific single example in support of this statement, a troublesome machining operation on brass forgings showed, in spite of constant inspection, a steady 15% scrap and rework loss. A week of Quality Control analysis, with charts, led to the overhaul of a turret lathe, to a redesign of tooling and to a change in the brass forging specifications. This engineering action, initialed and guided by the Quality Control analysis, reduced the direct operating losses from 15% to 3%.

In addition to the type of saving just exemplified the plant-wide use of Quality Control methods easily allowed a 50% reduction in our Inspection population and expense within a few weeks' time.

The contrast to be emphasized here, however, is the outstanding though seemingly paradoxical fact that product quality simultaneously improved. Furthermore it maintained a degree of dependability it had failed to possess before.

Industry should capitalize on this characteristic of product reliability which results from the use of Quality Control. Some alert manufacturers have already discovered the increased public acceptance of a product where it is known through advertising that a statistical Quality Control system is used in the surveillance of the process. Quality Control can be a business getter as well as a builder of good will.

An interesting and dividend paying variation of or addition to the important Quality Control graphic chart portrayal of operating and product conditions is to bring the picture home to the oper-

ator by supplying him with gages on which are plainly marked the so called "control" limits for his particular work. The worker, the man at the machine, becomes thus automatically an active participant in the Quality Control system.

Our active promotion of Quality Control stems from the belief that the prosperous survivor of the imminent surge of business and competition will be the maker of consistently high quality products and that Quality Control will prove an important factor toward obtaining this desired end.

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## OPTICAL

### "Post-War Expansion of Quality Control System"

THEODORE B. DRESCHER
Vice-President in Charge of Manufacture, Bausch & Lomb Optical Company

Any management, responsive to the ever-increasing pace of industry, is constantly on the alert for devices which will increase production, lower costs, and improve quality. Like many other companies under the extreme pressures of the war emergency, we have employed every means at our command to meet the admittedly fantastic production requirements of mechanized warfare.

While the control of quality has been the foundation upon which we have conducted our business for nearly a century and is therefore not new to us, the modern concepts of Statistical Quality Control have proven of inestimable value to us during the war years. Exactly as would be expected, we do not intend to relinguish any tool of management which can be useful in our peacetime production. For that reason we are well along with our plans for integrating Statistical Quality Control with our total operational plans.

A unique contribution is being made by a management-appointed committee, which coordinates the thinking and gives direction to our program. The Committee on Quality Control represents the manufacturing and engineering units of Bausch & Lomb and brings together the ideas from the various divisions.

Substantial results have been derived from the analytical research conducted by the members of this group. Numerous examples come to mind as illustrations of concrete savings.

In the Glass Plant careful charting of inspection results through three different levels of production has made readily possible the location of inferior performance of inspectors, machines, and operators. Timely correction of these constitutes obvious savings in wastes, rejects, and re-work. Charting the quality performance of a rapid-fire weighing machine enables us to detect faulty adjustment immediately and to correct the difficulty without "down time." This check materially increases production not only in this operation but also in succeeding grinding operations.

Charting the quality level of the Porro Prisms for our large binocular pointed out that the machinery which performed the preliminary grinding operations was capable of holding closer tolerance and producing a more uniform level of product. A 25 percent reduction in scrap and reoperation resulted which meant a monthly savings of $500 for material and labor on this part alone. See Fig. 1.

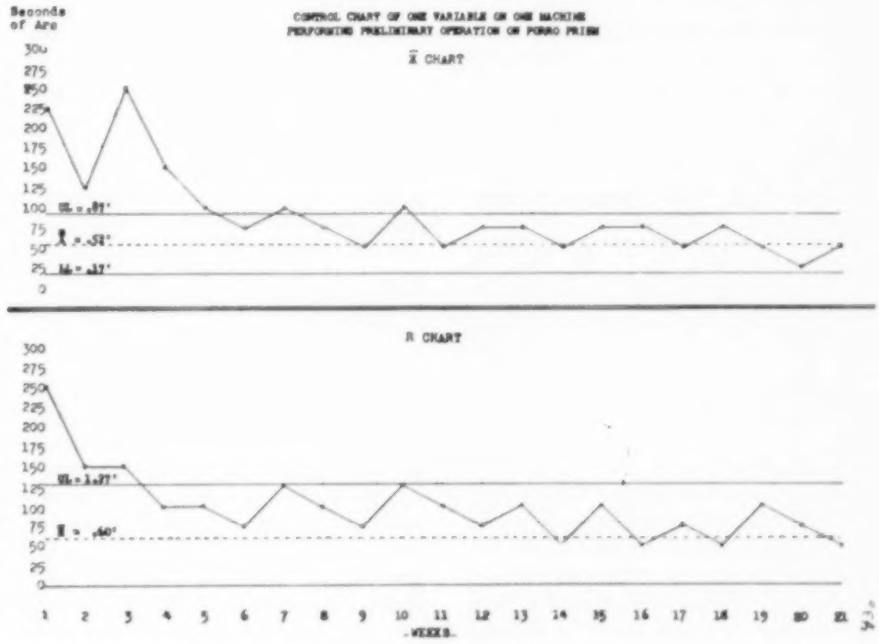
Extensive study has also been made on the relationship of tolerances to quality levels, production levels, and tool costs. In this study it has been observed that there is a definite principle of compensation of defects in optical instruments, where the sum total of defects through a series of prisms and lenses is not a true picture of the total error. One defect tends to compensate for another instead of adding to it.

Our Engineering Inspection Department has developed what we call an **index of quality.** This index was found to be necessary for proper analysis and recording of quality levels of extremely complex optical instruments. Number and percentage of rejections of these instruments is meaningless when there are so many possible variables. This situation suggested our establishing an evaluation of defects and a scale which takes into consideration the seriousness of the defect. From this scale we take a total weight of defects and divide by the total number of units inspected to get an index of quality. By use of this index in recording we were able to control and raise the quality levels of two wartime products while doubling and tripling our output. See Fig. 2.

In postwar production these methods will be very effective in controlling quality in highly complex instruments.

Our experience with Quality Control has been highly encouraging. The cost of the program is

Fig. 1



negligible when compared to the gains we have made through increased production, lowered manufacturing costs, and improved quality. For this reason we plan to extend systematically Statistical Quality Control through all manufacturing operations from the receiving of materials to the finished product. We feel that to have this quality information in tangible and understandable form is essential to the efficient production of high quality products, to which we have long been dedicated.

Additional specific instances of the value of Quality Control at Bausch & Lomb have been previously reported. Please refer to the July, 1945 issue of INDUSTRIAL QUALITY CONTROL.

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## CHEMICAL

### "Quality Control in Chemical Manufacture"

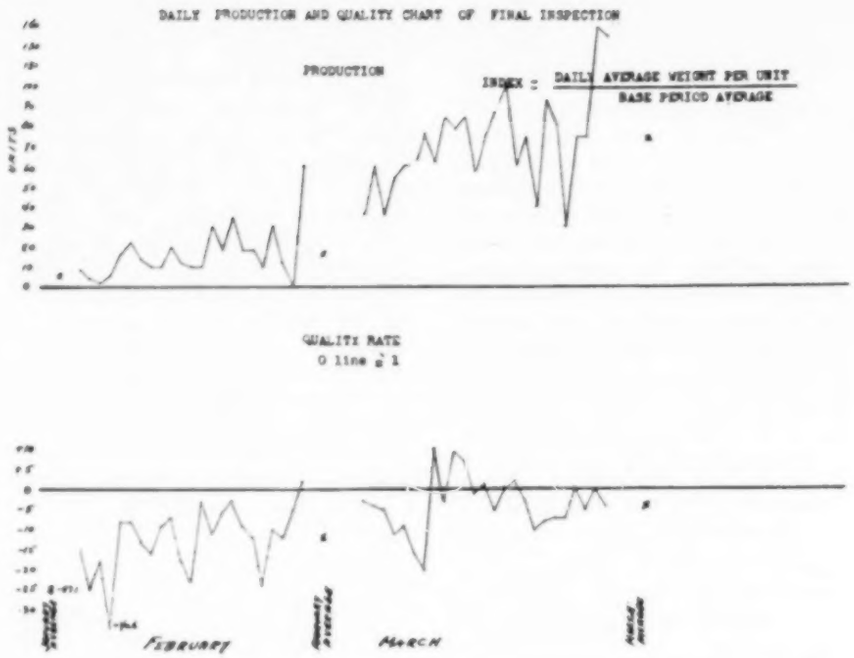
JAMES A. MITCHELL

Supervisor of Quality Control
Cellulose Esters Division
Tennessee Eastman Corporation

The science of quality control has proven to be a powerful tool in chemical manufacture at Tennessee Eastman Corporation. Highest quality products produced in the most efficient manner are the Eastman standards of performance, and the manufacture of chemicals and chemical products at Tennessee Eastman Corporation follows this policy. In the Cellulose Esters Division where cellulose esters of many types are produced for the manufacture of film, plastic, yarn, and other uses, the control of quality is of vital importance. A quality control department has been active in this division for many years. The original activities of this department were centered on trouble shooting and plant inspection and although these functions are still important, new quality control methods have been adopted and will continue to be adopted as they are proven.

The control of quality and efficiency in the chemical industry is a complex problem. Quality and Efficiency are dependent upon many variables, such as raw materials, operating equipment, operating

Fig. 2


DAILY PRODUCTION AND QUALITY CHART OF FINAL INSPECTION
PRODUCTION
INDEX = DAILY AVERAGE WEIGHT PER UNIT / BASE PERIOD AVERAGE
QUALITY RATE
0 line = 1
FEBRUARY
MARCH

procedures—including time, temperature, concentration, impurities, etc.—analytical control, sampling, and analytical inspection. The responsibility for producing quality material lies with the production departments but since responsibility for all of the controlling factors lies in many different departments some staff coordination is necessary for efficient production of high quality materials. Variables which enter the process in one department may subsequently affect quality and efficiency seriously in the later part of the process. All of the factors in the process affecting quality and efficiency must be examined with quality standards in mind and with a knowledge of the quality requirements of the customer. For these purposes the quality control department has been established as a staff department with direct responsibility to the superintendent of the Cellulose Esters Division.

Statistical quality control has been found very valuable in dealing with chemical problems in quality variations. The control chart can be used to differentiate between daily variations in quality and efficiency and variations which are due to an assignable cause. We have also been able to use the control chart to improve the quality of the raw materials received from our suppliers. In the chemical industry practically all inspections are performed by chemical and physical tests. The accuracy and precision of these tests can be effectively determined by the control chart method and this procedure has revealed the cause of many inspection problems.

When variations occur in the quality of a chemical product one of the most difficult problems is determining the cause of the variation. An investigation of these causes involves, of course, chemical and engineering experience and knowledge. But we have found that correlation studies will often reveal unsuspected causes of quality variation and will allow a more rigorous control of quality and efficiency.

We are still developing more effective methods of controlling quality and efficiency while we are using those which have been proven valuable. There has been a steady overall improvement of quality and efficiency since our adoption of these quality control techniques. Savings of hundreds of thousands of dollars have been realized this year.

## "Accuracy of Measurement"

Research Department, Imperial Chemical Industries Ltd., Metals Division, Birmingham, England

MAURICE MILBOURN, A.R.C.S., B.Sc., D.I.C.

The progress of modern industry is based on pure research, the results of which are applied in industrial research and development, leading to semi-plant scale experiments and eventually to production. At all stages of this cycle measurements are of paramount importance; they form, in fact, the foundation on which results are built, and it is essential therefore that they should be accurate. They may range in complexity from simple dimensional measurements to observations made with elaborate apparatus, but an assessment of accuracy is valuable in all cases.

A typical example is chemical analysis, which is used not only as a research tool, but also in production control. It has frequently been the practice to determine accuracy by means of relatively few repeat tests, ignoring variations which may be introduced by different operators working in other locations with different apparatus and reagents. When all sources of variations are taken into consideration, there will be a mass of data which can best be handled by statistical methods. A full analysis of data obtained in research problems, or a quality control chart on routine chemical results, would, in fact, give valuable information, leading to a better assessment not only of tests but of products. Similar examples could be quoted from the fields of mechanical and physical testing, which have led to modifications to equipment and procedure, giving improved results.

While is is necessary to know the accuracy, or more strictly, the reproductibility, of measurements, still more information can be obtained by regarding them in conjunction with the variations introduced in manufacture. They can all be studied by means of designed ed experiments, which are planned from a statistical point of view, and which will give the maximum amount of information from a limited number of tests. Designed experiments have been used for several years in agricultural research, following methods originated by Professor R. A. Fisher of Cambridge University, England. The advantages in this field are obvious, since each experiment takes a year to carry out, but they have been used very little in industry, although similar advantages could probably be gained. They would offer the minimum amount of hindrance to normal production and the information they supply would be a valuable aid in the economic control of manufacture.

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# RUBBER

## "Quality Control by Statistical Methods"

G. H. CASSADY

Manager—Quality Control Division Fisk Tire Plant

In any manufacturing process, the ideal objective is to make nothing but firsts. To have every piece of merchandise measure up to the specified standard of production is the dream of every quality control manager as well as every production manager. In the rubber industry this objective has never been consistently attained. Perhaps it never will be. There are however, ways and means of doing a better job than we have done in the past.

Up until the time Japanese aggression closed off the sources of crude rubber, quality control of stocks and processing was not particularly scientific nor maintained with very much exactitude. In fact minute control was not considered necessary because stocks made from crude rubber could take a lot of abuse without too much harmful effect on the quality of the finished product.

With the advent of synthetic polymers it was quickly discovered that the degree of control exercised for crude rubber stocks was not adequate for the synthetic stocks. Fortunately at about that same time quality control by statistical methods came into prominence. Its possibilities were recognized and many applications were initiated. The effectiveness of the methods were immediately apparent and their use was quickly expanded.

In spite of the new and unfamiliar basic raw materials, shortages and substitution of other materials, inexperienced help and many other difficulties, there were surprisingly few production interruptions due to stock troubles. Rapidly increased production schedules were met, defects and rejects were kept under close control and consistently high quality merchandise was produced.

Quality Control by statistical methods played an outstanding part in making such a performance possible. Its success during the war period assures its retention and expansion to make possible an even better peace time production. It is definitely a forward step in the rubber industry as it has already proved, during the short time it has been tried, to be one of the most promising ways to produce uniformly high quality with fewer rejects.

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# TEXTILE

## "Statistical Control a Permanent Feature"

A. G. ASHCROFT

Director of Research Alexander Smith & Sons Carpet Company

We began the application of statistical techniques and the use of the control chart method in the Research and Product Engineering Laboratories of this company in 1934. We applied the techniques first to the testing of purchased cotton and jute yarns, and later to the methods of testing and reporting our own manufactured yarns and finished product.

We have found these statistical techniques of great value in the development of understanding of the variables in materials, and the techniques are now an accepted part of our quality control process. The sources of supply are sent reports, based on control chart data, and all of our supervisors and superintendents are familiar with and use the control chart records as part of their method of bringing about better control of quality, or changing levels of quality.

During the war we made excellent use of our experience with these techniques in connection with the maintenance of standards of quality, and the meeting of specifications in the manufacture of Army and Navy blankets and

heavy cotton duck. During recent years we have also applied these techniques with pleasing success in development work in connection with test methods, processing changes and comparison of equipment.

There is no question but what the techniques, as an over-all picture, have resulted in reduction of losses in purchase of materials and in the manufacturing of a more uniform product.

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## AIR CONDITIONING

## "Quality Control"

E. F. GRAUMENZ

Carrier Corporation
Quality Engineer

A prime objective of the Carrier Corporation, manufacturers of air conditioning and refrigeration equipment, is to produce a maximum of goods at the lowest possible cost with the highest possible quality.

With this objective in mind the Inspection Department, as its contribution to this cause, in January 1944 gave serious consideration to the use of Quality Control as one of the tools to achieve this end. After considerable study of the problem a start was made on a Quality Control System to acquaint operators, foremen, inspectors and supervisors with its advantages, its procedures and use of the control charts. The first results showed immediate promise and this system is now being carefully expanded to meet those needs which will readily return the best results.

### Quality Control in Receiving Inspection

During the war period control of inspection costs and the quality standards of purchased items deteriorated considerably in the interest of high production and the difficulties of material procurement. This situation immediately challenged the postwar activities of the Inspection Department and at the same time appeared to offer a promising field for the use of statistical control. Accordingly a careful study was made of existing inspection procedures, prior deviations from sound and accurate inspection practices, condition of gages and the record keeping system.

As a result of this study many inspection procedures were rewritten—drawing tolerances were again considered inviolate and sampling methods established. The percent defective cycles on incoming lots of materials were recorded and filed under vendor name and these data were submitted to the Purchasing Department for its records and for transmission to vendors. Additional records indicated in many instances the advisability of modifications on drawings and recommendations were submitted to the Engineering Department with beneficial cost results.

Although the use of Statistical Quality Control in the Carrier Receiving Inspection Department has not yet been fully tested by time, the indicated results are very gratifying.

It appears that the following results are being achieved:

1. A 30% reduction in the inspection staff.
2. Increased volume of material inspected.
3. A definite decrease in the rejects received from vendors indicating a stimulation of their quality consciousness.
4. A comparison of vendors on the basis of quality.
5. A definite program of holding drawing tolerances, or revising unusually tight dimensions, if this action seems profitable and does not impair the function of the part.
6. A general uplift in the quality consciousness of the Carrier Inspection Department.

### Quality Control in other Departments

While we have not yet produced the definite costs results in the other departments which have been obtained in Receiving Inspection, trouble shooting with Quality Control has brought forward some interesting as well as profitable results.

Faced with a demand for larger quantities of cast iron pressure castings from foundries which have been depleted of skilled moulders, the problem of obtaining sound non-porous castings for the production line is a staggering one. Here statistical control is doing an excellent job. Every shipment is immediately sampled upon receipt at the factory and data collected on rough dimensions, core or other shifts, excessive finishes and porosity. If trouble is indicated, and it generally is, a casting expert is dispatched to the foundry where he gives his assistance in an immediate correction of the trouble, even to the extent of pattern revisions, before hundreds of other castings have already been defectively made. The saving in production time and actual casting cost is obvious.

As the manufacturing process goes forward, more leisurely data are obtained and these data are studied for possible pattern revisions or changes in foundry technique which are then transmitted to the foundry. Here indeed does this new tool of industry, Statistical Quality Control, satisfy the demands for accuracy, speed and quantity production! At Carrier rejections of badly needed castings in some instances have been reduced from as high as 43% to a level of 8% and this low level is being consistently maintained.

In the prime surface coil department a statistical study of the number of leaks and the cost of repairing them was instigated as a trouble shooting tool. Records were obtained on the number of leaks, type of leaks and the man-hour time of repair. These data were plotted and the defective cycles formulated.

A study of these simple data revealed that astonishingly large losses were being accepted as a matter of general manufacturing procedure probably because the complete facts had never before been presented to Production. Initial reports on this particular problem indicated a process average of 30% defective with man-hour repair time of 120 minutes per coil. As a result of this study the welding and assembly procedures were revised and one worker producing a high percentage of defective work was transferred to another job. Later studies indicated the process average defective to be 6.6% with a repair time of 30 minutes per coil.

In a similar manner a statistical study of the breakage of ribbons being wound on copper tubing not only indicated that some action

was necessary on the quality of the ribbon but further proved very definitely that, out of a battery of 8 winding machines, one was mechanically defective. Furthermore these data indicated the possibility that one operator was not familiar with his work or did not have the proper skill for this type of work.

At Carrier Corporation we have made a modest beginning with this new tool of industry—the indicated results are very promising. We believe that, aside from the direct savings that seem apparent, of no less importance is the indirect benefit of the stimulated interest of the workman and supervisors in the solution and correction of their many annoying and costly problems. We intend to apply this new tool in whatever direction it may best serve the prime objective of the corporation.

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## DISTRIBUTION

### "Control Charts Locate Errors"

JAMES M. BALLOWE
Manager of the
Quality Inspection Department,
Aldens Chicago Mail Order Co.

At Aldens we are using NP charts in all of our merchandise departments, the shipping room, billing, returned goods, and in all of our General Office clerical departments.

During the first three months of 1945, before the installation of Quality Control by Statistical Methods, 32.4 per cent of adjustments with customers were attributed to errors made by the merchandise departments. This figure dropped to 27.1 per cent in April during which time the methods were used in five of the principal error making departments. From May to September inclusive, after the methods were adopted by all departments, the figure was further reduced to 23.8 per cent.

In the order reading department of our General Offices, the per cent of errors was reduced by one-half within three months after the program began. In our other clerical departments the progress has been less spectacular but we have arrested a trend which was previously in the opposite direction and have made a gradual and consistent improvement.

## RECEIVING INSPECTION

### "Quality Control in Receiving Inspection"

O. W. HITCHCOCK
Quality Manager
Scintilla Magneto Division
Bendix Aviation Corporation

We are now living in an age when planning plays a predominant role. In Government, in Industry, and in private affairs, planning precedes building. To build we must plan. During the war when Industry was willing to adopt any procedure that might conserve manpower, materials, or time, Statistical Quality Control was introduced in many plants. The Scintilla Magneto Division feels that the use of statistical methods is a contribution to Inspection that has been long awaited.

In the Receiving Inspection, statistical techniques have done much to adjust and put inspection where it is needed. Quality Control Records have brought to light varying standards of inspection, overinspection, and inadequate inspection. In many instances, sampling methods have replaced 100% inspection which for a long time had been thought necessary to assure high quality in the finished product. For example—in the manufacturing of high tension condensers it had been a practice to inspect each mica plate. This was to insure a minimum of burnouts on final test and to give each condenser the correct capacity. Records showed that the rejections for condensers were exceedingly low, 0.3%. However, the Quality Manager felt that the number of persons required to inspect mica was excessive and recommended a sampling procedure. Instituting the sampling plan led to better methods, improved inspection procedures, and reduced the personnel from 25 to 2—while the frequency of condenser rejections remained at the same level, approximately 3 out of 1000 units. In the above case, the specification for 100% inspection had failed to take into account that excessive handling was detrimental to the process. The new method of inspection brought about an improvement in vendor relations which alone was well worth the effort expended.

Statistical techniques have made it possible to reduce Receiving Inspection at Scintilla 25%, speed up the work on many jobs, and still keep the emphasis on quality. Furthermore, it has given Inspection a more scientific approach to its problems and has helped both the vendor and the Company in controlling quality.

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## SUB-ASSEMBLY INSPECTION

### "Sub-Assembly Inspection Pays Dividends"

H. H. KENT
Eastman Kodak Company

Sub-assembly inspection is one of the more important tools in the inspection supervisor's tool box. However, in some cases, the inspector does not know it is there or exactly how to put it to work. It has been found that if the rust is removed it becomes a very fine instrument that will go a long way in guaranteeing quality and at the same time reduce cost. It necessarily forces all inspectors to become more intimately acquainted with the product and allows the inspector to become of maximum assistance to the production group.

As most Production Departments are necessarily interested in schedules, quality, and cost in probably the order listed, it is important that the inspectors be of maximum service and perform their duties promptly and with maximum efficiency. Some of the gains to be derived from this sub-assembly inspection are:

A. Reduction of Final Inspection costs with the knowledge that better quality is built into the unit.

B. Reduction of Assembly repair costs by calling the repair condition to the attention of production before hundreds or thousands of units are produced in error, or assembled into larger sub-assemblies or completed units.

C. Improved quality from production operators as they will all know that quality must be built-in or the parts will be returned to them.

D. Less department scrap.

E. Fewer Final Inspection repairs which will allow the use of sampling procedures.

F. General improvement in the attitude or state of mind of Inspection and Production operators whereby teamwork is realized to accomplish the one common goal.

It has been most difficult, in some cases, to install sub-assembly inspection and take advantage of its maximum possible benefits. This generally is due to tradition or failure of inspection to understand fully how to function and cooperate without upsetting the normal production flow. To make this practice work, the inspection supervision must be very capable and experienced and have aggressive, willing and understanding inspectors. At times the fault may lie with Production due to lack of understanding of how sub-assembly inspection can help them produce more work with fewer repairs. This understanding is basic if this type of inspection is to function and there must be clear understanding that, no matter how many inspectors are present, it was the production people who built the quality into the product. It is also important that the understanding is that quality built in the first time is of higher value than quality built in on a second try by rework or readjustment.

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## FINAL INSPECTION

### "The Money Value of Industrial Statistics"

PAUL PEACH
Institute of Statistics
University of North Carolina

Impressive savings have been made by the use of statistical methods of quality control during a production process. Of almost equal importance are applications of statistics to industrial testing—in which I include visual and gage inspection, physical testing, and chemical analyses.

Each of these jobs seeks to obtain information with a view to directing subsequent action. The questions "How much information, of what kind, do we need, and what kind of action can we reasonably take?" can be answered only by statistics. Too often these questions have been ignored, with one of two results usually following. Either testing has been on so small a scale that the results have been practically worthless, or, in an attempt to "play safe," the scale of testing has been extravagantly large.

I encountered examples of both kinds at the old Milwaukee Ordnance Plant. One had to do with the testing of primers (the small percussion cap in the head of a cartridge). The test consisted of dropping a weight on a primer and observing whether it did or did not fire (explode). The blow could be adjusted by changing the distance of fall, and the old specifications required that all primers of a lot must fire at a 15" drop, and none must fire at a 5" drop.

Of course the specification was bad, since there was no way of telling whether a lot of primers was good or bad except by firing them all. (A lot consisted of about 90,000 primers.) In practice, inspection consisted of testing 100 primers at the 15" drop and 25 at the 5" drop; in case of a failure at either drop, a retest was allowed with a doubled sample. One need not be a statistician to see how ridiculously inadequate this test was. At worst, defective primers are rare, and ordinarily a lot of 90,000 would contain none, seldom more than 2 or 3. But on the basis of testing 100 specimens, a lot would have to contain over 600 bad primers in order that there might be a 50-50 chance to reject it. With a dozen lots tested a day, the cost was around $100, or $30,000 a year **dead loss**—money thrown away on a test which, as then used, could not possibly provide any useful information.

On the basis of a statistical study we set up a scientific method of testing that gave us accurate and usable information. The cost was about 30% more than by the old method. By spending $10,000 more a year, we converted a $30,000 waste into something valuable and useful. (By one of those coincidences so common in scientific work, essentially the same method was discovered simultaneously and independently by Moreland at Minneapolis and Churchman at Frankford Arsenal.)

In the example just described, money had to be spent to convert a useless test into a useful one. This did not always happen; about as often as not we found it possible to improve the efficiency of testing and at the same time lower the cost. In the "function and casualty" test we reduced testing by 80%, saving at least $200 a day and yet obtaining adequate information. Our daily savings on accuracy testing were well over $1,000 a day; this job involved finding an approximate solution to a problem in mathematical statistics which is, I believe, still without an exact solution. By placing our final inspection on a control chart basis we were able to cut the amount of inspection by 70%, saving around $50,000 a year in wages alone, to say nothing of such items as gage cost. All these savings and many more were made possible by the Quality Analysis Department, with a peak of 30 people and an annual payroll of around $75,000.

Perhaps the most important saving of all, though not easily estimated in dollars, was the confidence we acquired through having dependable quality information. Prior to the introduction of statistical methods of estimation nobody knew just where our factory stood with regard to quality. There can be no doubt that considerable quantities of acceptable product were downgraded or scrapped as a result of this confusion. Too many factories today, as far as their quality policy is concerned, are trying to drive along a pitch-dark road without any lights. They need the illumination that can be obtained by the intelligent application of statistical methods.

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## SUMMARY

### "Implications of Statistical Quality Control"

RALPH E. WAREHAM
Consultant on Quality Control

On any manufactured product, there is an important job to do in controlling quality. American trade names have stood for high quality in the past and that quality must be even more closely controlled in the future.

Experience has shown that product quality can be controlled by effective use of the trained personnel, the know-how, and the equipment available. It is primarily a problem of organizing

our efforts. Quality control is something that we can all do well and our quality control methods can be improved with experience. The actual applications will prove very interesting.

However, quality control is not something that can be done once and then forgotten. The secret of controlling product quality is keeping a continual light check on the manufacturing process to be sure that quality does not change. There is always the possibility of doing a job better and better by continued correction of the troubles that occur.

A successful program of quality control will assist greatly in turning out a smooth flow of high quality products at low cost. As a management tool, quality control will provide:

(a) Better quality through better design as a result of improved knowledge about factory processes, and

(b) Better equipment and processes by stimulating manufacturing studies, and

(c) Better quality safeguards by improved inspection methods.

These three gains will together bring steady improvement in quality and reduction in costs. These are the import of quality control.

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## EDITOR'S SUMMARY

Martin A. Brumbaugh

This special issue of INDUSTRIAL QUALITY CONTROL has been prepared for the express purpose of bringing to the attention of management concrete evidence of (1) the present state of quality control work in industry; (2) the variety of situations and types of industry in which quality control techniques are employed; (3) the point of view of quality control operators.

From editing this series of articles three pertinent observations emerge.

(1) The many "cases" reported in this issue are not even a representative sample of the quality control work in progress in the United States and Canada.

(2) Many of the most important gains from the use of quality control cannot be reported because they are being held as competitive secrets.

(3) New applications are appearing at a rate which makes it impossible for any one individual to be aware of even a major fraction of them.

Following are a few stories from the author's personal experience which will illustrate observation (2) of the preceding paragraph. Under no circumstances could the source of any of these statements be revealed.

(1) In a large machine shop rework and scrap were reduced from 17% of production to 3%. The evaluated saving was $6700 per week, but the intangible benefits in the form of better relations between inspection and production, and between tool engineering and production probably exceeded the monetary saving. The weekly payroll of the quality control department was about $500.

(2) Rejections of a composition building material were reduced from 20% of production to less than 1% by the single device of reducing by 10 degrees the temperature of a drying oven. The unit value of the product was small but the volume was enormous. The greatest saving came from elimination of the handling cost of scrap. An engineer from the company's research laboratory conducted this investigation as a corollary to his regular job, hence the separable cost of the improvement was zero.

(3) The introduction of control of the steam pressure of a reducing furnace and the subsequent adjustment of the average level of the steam pressure resulted in an annual increase in the recovery of product worth $300,000 from a battery of furnaces. The total cost was represented by the construction of a pilot furnace in the laboratory for demonstration purposes.

(4) A quality control engineer catalogued and aided in the elimination of surface decarbonization and allied faults in the manufacture of steel with evaluated savings of $250,000 per year. The entire system was operated by the engineer and one computing clerk.

(5) Control of the dimensions of the components of a complicated product reduced rejections from 30% to 1%, saved one-half of the former assembly time, and permitted delivery of finished product to the Navy ahead of schedule, thus aiding the speed-up of the war in the Pacific. Two inspection supervisors and two recording clerks were relieved of their other duties to carry on this work.

(6) Control of one dimension in a metal stamping operation permitted selective assembly to be replaced by random assembly of the product. The saving per unit exceeded four cents on a daily output of more than 3000 assemblies. In addition, the cost of the stamping operation was actually reduced to a point at which the standards department revalued the job. The improvement was brought about by the chief inspector as a routine part of his job.

(7) Through the introduction of a scientific sampling plan in receiving inspection, a plant was able to abandon most of its 100% inspection and fixed percentage sampling plans. Since the plant purchased standard parts in large quantities, it was able to maintain quality assurance by inspection of only 2% to 3% of the more than 300,000 pieces received per week. The results were, a sharp reduction in complaints of faulty parts reaching the assembly line, the speedy elimination of "bottleneck" conditions in the receiving area, and a reduction in receiving inspection cost amounting to over $200 per week.

(8) A manufacturer making nonferrous rods from blended powder was plagued with excessive rejections which seemed to arise in the operation of swaging the moulded ingots. Failure to detect the cause at this point led to an intensive study of the original blending of the powder. Careful control of the distribution of particle sizes in the blending stage eliminated much of the trouble. As a collateral result the temperatures of the gas ovens of the swaging machines were more closely controlled and the setting of the centerless grinders was improved. This program entailed considerable expense, but the saving in scrap of a high valued product amounted to many times the cost of the quality control installation.

There is literally no limit to the assistance which a quality control program can render to industry. Management should be on the alert now to take advantage of this tool for industrial progress.

Dimensional quality is controlled directly at the machine.

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